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MAGNETIC RECORDING MEDIUM FOR VERTICAL RECORDING
[Suichoku Kiroku Jiki Kiroku Baitai]

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1. Title of the Invention: MAGNETIC RECORDING MEDIUM FOR VERTICAL RECORDING

2. Claims

1. A magnetic recording medium for a vertical recording, characterized by being equipped with a nonmagnetic substrate, a Co-Cr vertically magnetized film, and a permalloy film which is interposed between the above-mentioned substrate and the above-mentioned Co-Cr vertically magnetized film and includes at least one nonmagnetic layer and in which at least two layers of layers divided by the nonmagnetic layer have a thickness different from each other.

2. The magnetic recording medium for a vertical recording of Claim 1, characterized by the fact that the above-mentioned two layers are an upper layer nearest to the Co-Cr vertically magnetized film and a lower layer nearest to the nonmagnetic substrate; and the upper layer has a thickness thinner than the lower layer.

3. The magnetic recording medium for a vertical recording of Claim 2, characterized by the fact that the above-mentioned nonmagnetic layer is Ti.

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[1] Numbers in the margin indicate pagination in the foreign text.

4. A magnetic recording medium for a vertical recording, characterized by being equipped with a nonmagnetic substrate, a Co-Cr vertically magnetized film, a permalloy film which is interposed between the above-mentioned substrate and the above-mentioned Co-Cr vertically magnetized film and includes at least one nonmagnetic layer and in which at least two layers of layers divided by the nonmagnetic layer have a thickness different from each other, and a nonmagnetic layer disposed between the above-mentioned Co-Cr vertically magnetized film and the above-mentioned permalloy film.

3. Detailed explanation of the invention

(Industrial application field)

The present invention pertains to a magnetic recording medium for a vertical recording with an excellent high-density recording characteristic.

(Constitution of prior art and its problems)

As a magnetic recording method with excellent short-wavelength recording characteristics, there is a vertical magnetic recording method. In the method, a vertical magnetic recording medium in which the direction approximately perpendicular to the film surface of the medium is an easy axis of magnetization is required. If a signal is recorded on such a medium, the residual magnetization is approximately perpendicular to the film surface of the medium, so that the demagnetizing field in the medium is reduced with the signal becomes a short

wavelength, thereby being able to obtain an excellent reproducing output. A Co-Cr vertical magnetic recording medium called a monolayer film medium is formed by applying a sputtering method or a vacuum deposition method (also including a method that ionizes part of evaporating atoms and /2
vapor-deposits them, like an ion plating method) to a vertically magnetized film mainly composed of Co-Cr on a substrate made of a nonmagnetic material. For the monolayer film medium with such a structure, it is known that the recording efficiency and the reproducing output are improved by adopting a structure so-called a two-layer film medium in which a permalloy film 3 is installed between a substrate 1 made of a nonmagnetic material and a Co-Cr vertically magnetized film as shown in Figure 1. In particular, in recording and reproducing using a well-known auxiliary magnetic pole excitation type vertical head, the recording efficiency is improved by about 20 dB, and the reproducing output is improved by about 20 dB.

As mentioned above, with the use of the two-layer film medium, excellent recording and reproducing characteristics are obtained. However, in consideration of the high densification and the miniaturization of a magnetic recording and reproducing device, the characteristics are still not sufficient, and more excellent characteristics have been in demand.

(Purpose of the invention)

The purpose of the present invention is to provide a magnetic recording medium for a vertical recording having

recording and reproducing characteristics superior to those of the conventional two-layer film medium.

(Constitution of invention)

The magnetic recording medium for a vertical recording of the present invention is equipped with a nonmagnetic substrate, a Co-Cr vertically magnetized film, and a permalloy film which is interposed between the above-mentioned substrate and the above-mentioned Co-Cr vertically magnetized film and includes at least one nonmagnetic layer and in which at least two layers of layers divided by the nonmagnetic layer have a thickness different from each other.

(Explanation of application examples)

An application example of the present invention is explained referring to Figures 2-6. Any of Figures 2(A) and (B) shows a two-layer film medium in which a permalloy film 4 and a Co-Cr vertically magnetized film 2 are sequentially formed on a nonmagnetic substrate 1 as a basic structure. In Figure 2(A), the permalloy film 4 is separated into two layers of an upper layer 5a and a lower layer 5b by one nonmagnetic layer 6. Also, in Figure 2(B), the permalloy film 4 is separated into three layers of an upper layer 5a, an intermediate layer 5c, and a lower layer 5b by two nonmagnetic layers 6 and 6'.

Next, the recording and reproducing characteristics of the two-layer film medium in which the permalloy film has a multilayer structure are explained. Figure 3 shows a reproducing output in the case where the total film thickness of the

permalloy film and the structure are changed in the two-layer film medium. Also, the film thickness of the Co-Cr vertically magnetized film is as constant as 0.2 μm. Also, a signal is recorded and reproduced by a well-known auxiliary magnetic pole excitation type vertical head, and the recording density is 50 KFRPI. Also, the 50 KFRPI is a recorded state of a digital signal with 50,000 times magnetic reversal per 1 inch. Curves 7, 8, and 9 in Figure 3 are respectively two-layer media with a mono-layer structure, a two-layer structure, and a three-layer structure of a permalloy film. Figure 3 shows the relationship between the total film thickness and the reproducing output of the permalloy film in these each structure. From the figure, it is understood that when the total film thickness of the permalloy film is constant, the permalloy film has a multilayer structure and the reproducing output also increases with the increase of the number of layer. The reason for this is due to the size of the permeability μ of the permalloy film, and it is considered that μ of the film is increased as the thickness per one layer is thinned.

Next, the thickness of each layer of the permalloy film with a multilayer structure is explained. Figure 4 is a graph showing the reproducing output and the noise when the thickness of each layer of a permalloy film in a two-layer film medium in which the permalloy film has a two-layer structure is changed. In the figure, the total film thickness of the permalloy film is as constant as 0.4 μm, and the reproducing output (shown by white

circles) and the noise level (shown by black circles) are investigated for the following each two-layer film medium sample P, A, and B.

試料	パーマロイ膜
P	単層構造
A	2層構造であって、上層および下層がいずれも厚さ0.2μm
B	2層構造であって、上層および下層の厚さがそれぞれ0.1μmおよび0.3μm
C	2層構造であって、上層および下層の厚さがそれぞれ0.3μmおよび0.1μm

1. Sample
2. Structure of permalloy film
3. Monolayer structure
4. Two-layer structure in which both the upper layer and the lower layer have a thickness of 0.2 μm
5. Two-layer structure in which the upper layer and the lower layer have a thickness of 0.1 μm and 0.3 μm, respectively
6. Two-layer structure in which the upper layer and the lower layer have a thickness of 0.3 μm and 0.1 μm, respectively

Also, the reproducing output and the noise level are based on the conventional two-layer film medium (sample P). Also, the recording and reproducing were carried out by a well-known

auxiliary magnetic pole excitation type vertical head, and the recording density was set to 50 KFRPI.

As seen from Figure 4, the reproducing output for any of the two-layer film media of the samples A, B, and C is + 6 dB to the /3 conventional two-layer film medium (P). On the other hand, in the noise level, the samples B and P are almost the same, however the samples A and C are respectively + 6 dB and + 3 dB to P. Therefore, S/N (the ratio of signal to noise) of A, B, and C is respectively 0 dB, + 6 dB, and + 3 dB to the sample P, and the sample B is most excellent.

As mentioned above, in the two-layer film medium in which the permalloy film 4 has a two-layer structure, it is understood that reproducing signals with S/N superior to that of the conventional two-layer film medium can be obtained by changing the thickness of the upper layer 5a and the lower layer 5b of the permalloy film. Furthermore, like the sample B, the thickness of the permalloy layer nearest to the Co-Cr vertically magnetized film 2 is thinner than the thickness of the permalloy layer nearest to the nonmagnetic substrate 1, so that a reproducing signal with S/N superior to that of its opposite case can be obtained. It was confirmed from experiments that the above conclusion could be obtained for the case of three-layer structure or more as well as the case of the two-layer structure of the permalloy film 4. In other words, in the permalloy film 4 with a three-layer structure, a more excellent S/N is also

obtained by thickening the thickness of the lower layer 5b to the upper layer 5a of the permalloy film shown in Figure 2(B).

For the combination of the two-layer film medium and the auxiliary magnetic pole excitation type vertical head, the interaction between both of them is very large, and the recording and reproducing mechanism and concept are totally different from the combination of a conventional in-plane magnetized medium and a ring type head. Furthermore, since there is an interaction between the Co-Cr vertically magnetized film and the permalloy film in the two-layer film medium itself, in actuality, the recording and reproducing mechanism in the vertical magnetic recording is seldom elucidated, yet. For this reason, it is difficult to clarify the reason why the two-layer film medium of the present invention has a superiority to the prior arts, however the reason is considered that the action of the permalloy film as part of the head in the medium of the present invention is closer to an ideal action, compared with the prior arts.

The nonmagnetic layers 6 and 6' in the permalloy film may be any of Al, Si, Cu, Ti, Al_2O_3, SiO_2, etc., however it was clarified from experimental results that Ti was most appropriate. In other words, in the two-layer film medium, the c-axis of a close-packed hexagonal structure of the Co-Cr vertically magnetized film must be oriented in the direction perpendicular to the film surface, however the orientation is most excellent when Ti is used as the above-mentioned nonmagnetic layer.

Next, the present invention is explained by detailed

examples.

Example 1: An example is explained referring to Figure 5. In the figure, 10 is a polyethylene terephthalate film with a film thickness of 50 μm. 11 is a permalloy film with a two-layer structure and consists of an upper layer 12a with a thickness of 0.15 μm, a lower layer 12b with a thickness of 0.28 μm, and a Ti film 13 with a thickness of 0.015 μm. 14 is a Co-Cr vertically magnetized film with a film thickness of 0.18 μm. When a signal of 100 KFRPI was recorded and reproduced on a two-layer film medium with such a structure by an auxiliary magnetic pole excitation type vertical head, 28 dB higher S/N was obtained, compared with a conventional Co-included iron oxide spread type medium. Also, for a two-layer film medium with the same structure as that of Figure 5 except that the permalloy film was a monolayer structure and the film thickness was 0.43 μm, S/N of + 7 dB was obtained.

Example 2: An example is explained referring to Figure 6. In the figure, 10 and 14 are the same as those of Example 1. 15 is a permalloy film with a three-layer structure and consists of an upper layer 16a and an intermediate layer 16 with a thickness of 0.07 μm, a lower layer 16b with a thickness of 0.28 μm, and Ti films 17 and 17' with a thickness of 0.015 μm. When a signal of 100 KFRPI was recorded and reproduced on a two-layer film medium with such a structure by an auxiliary magnetic pole excitation type vertical head, 31 dB higher S/N was obtained, compared with a conventional Co-included iron oxide spread type medium.

Also, in the above-mentioned examples, the two-layer film medium in which the Co-Cr vertically magnetized film was directly formed on the permalloy film was explained, however as shown in Figure 7, even if a nonmagnetic layer 18 was disposed between two films 2 and 4, results similar to those of the above-mentioned examples were obtained when the film thickness of the nonmagnetic layer 18 was about 0.05 μm or less. Also, when the nonmagnetic layer 18 was changed to a TI or amorphous layer, the vertical orientation of c-axis of the Co-Cr vertically magnetized film 2 was largely improved.

(Effects of the invention)

According to the present invention, a magnetic recording /4
medium for a vertical recording with excellent recording and reproducing characteristics can be provided.

4. <u>Brief description of the figures</u>

Figure 1 is a cross section showing a conventional two-layer film medium. Figure 2 is a cross section showing an example of the two-layer film medium of the present invention. Figures 3 and 4 are graphs showing the reproducing characteristics of each two-layer film medium. Figures 5 and 6 are cross sections for explaining a detailed example of the present invention. Figure 7 is a cross section showing another example of the present invention.

1 Nonmagnetic substrate

2 Co-Cr vertically magnetized film

3 Permalloy film with a monolayer structure

4, 11, 15 Permalloy film with a multilayer structure

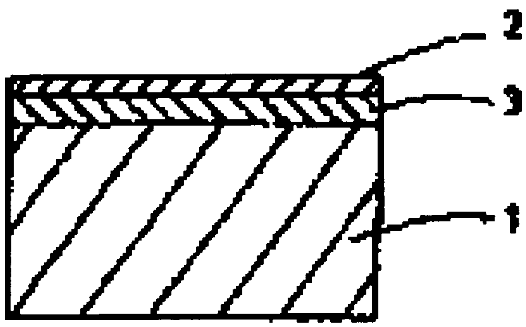
5a, 12a, 16a Upper layers

5b, 12b, 16b Lower layers

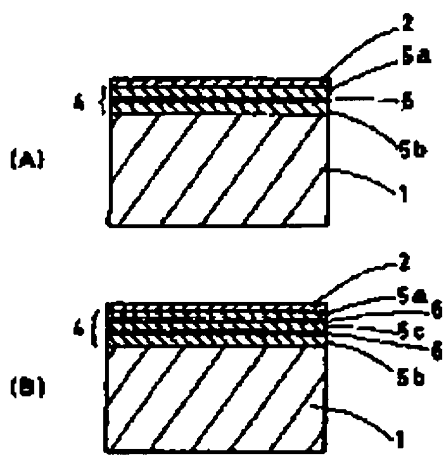
6, 6', 18 Nonmagnetic layers

13, 17, 17' Ti films

// Insert Figures 1-7 //



第 1 図



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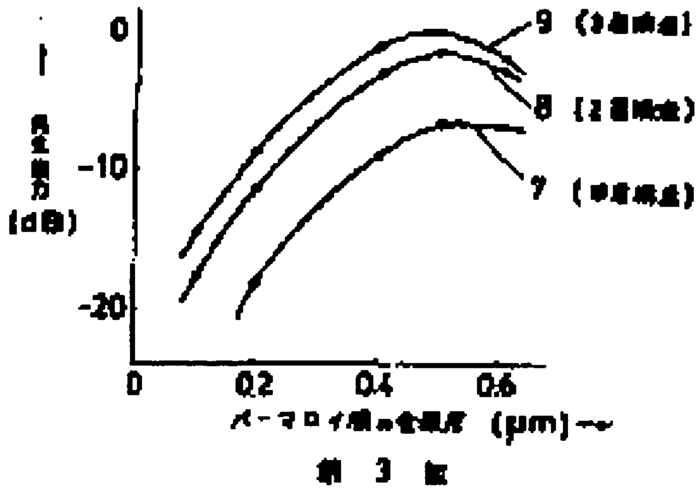


Figure 3:

1. Reproducing output (dB)
2. Total film thickness of permalloy film (μm)
3. Three-layer structure
4. Two-layer structure
5. Monolayer structure

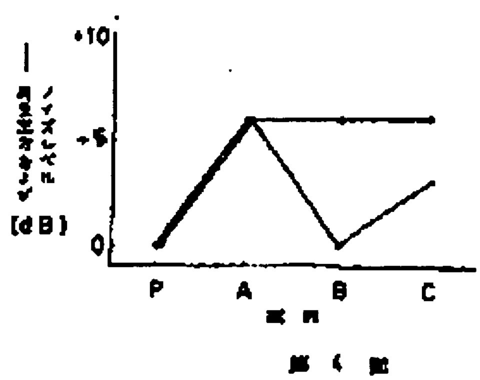
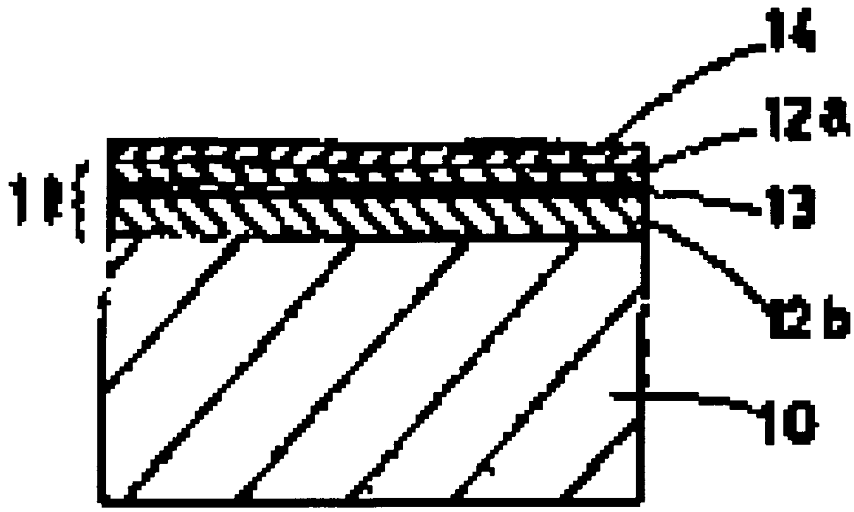


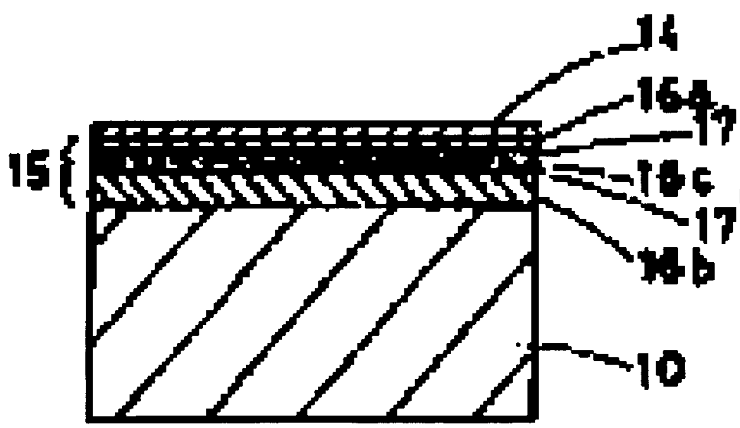
Figure 4:

1. Reproducing output and noise level (dB)

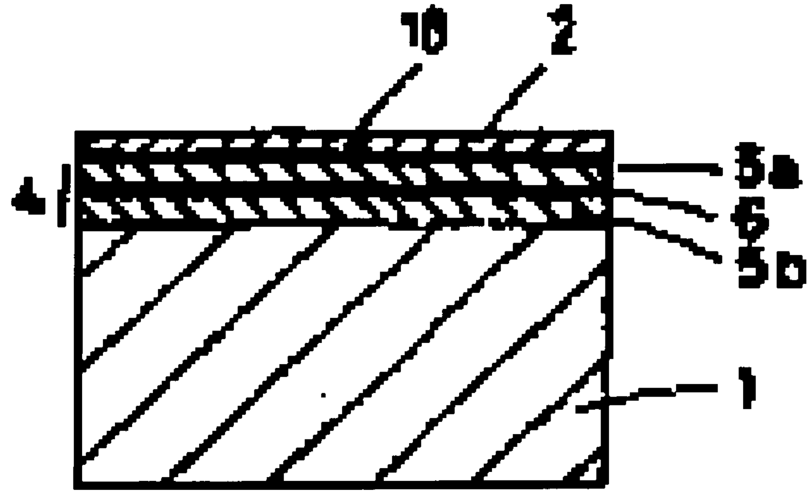
2. Sample



第 5 図



第 6 図



第 1 図